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THE CONFUSION BUTTON: A Formative Assessment to Identify Real-Time Student Misconceptions

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ABSTRACT

In a perfect world, instructors would be able to share information in class and at the same time, be assured that students understood the concepts as they were being taught. Historically, instructors have attempted to determine student understanding by simply asking if there are any questions about the material (of which, there are typically none), or employing various low or high tech student response systems, which provide a sense of which students can answer a provided prompt.

This study explores a new approach to gathering real time student understanding of material being presented. A program has been created and currently being piloted, which allows students to indicate their "confusion" on a topic, as it is being taught by pressing the volume button on their mobile phone/device.

The only requirement is that the device/hardware owned by the students could connect to the internet. On a very high level, Student signals produce an anonymous aggregate signal to the instructor desktop computer, which graphs time vs. number and level of student confusion.

In this way, instructors can stop discussing and address the confusion and/or proceed and after the class session view and address the problem, knowing precisely on what concept the confusion occurred. This paper presents early development, faculty and student attitudes and processes for implementation.

Keywords: Confusion, Student Response Systems, Formative Assessment, Active Learning, Large Classrooms, Student Interactions.

INTRODUCTION

The derivation of this study originated from an initial experience as a Teaching Assistant (TA) at a research intensive university assisting a large class. On the first day of class, I tried to lecture to 300 students. I had no idea if they were understanding, if they were following my presentation, or how they were making sense of the material. So I offered office hours to provide assistance, although only a few students attended.

I was disappointed at the outcome, perhaps mainly because I was aware of the problems they were experiencing as I experienced similar challenges as a student as well.

A different method was needed, for students to share with instructors what they know and when there were not following the lecture and especially the specific time when they became confused. An efficient approach is for students to discuss and work more cooperatively without taking the valuable time of the lecture class.

The goal then became to create a learning strategy thatwas more connected and personalized.

For this study, a personalised, data driven student response system (SRS) was created that addresses many of the challenges of the modern lecture hall using statistical machine learning and natural language processing algorithms.

The SRS provides a modular platform that caters to instructors' needs while also having the ability to grow into ideas that they believe are needed. This is accomplished while providing students with a mechanism to gain personal attention in a non-personal environment in today's growing classroom sizes. The system addresses these needs with the help of the following three features:

- ✓ **Confusion Button**
- ✓ **Question Curation**
- ✓ **Reflective Assessment**

The confusion of conceptual frameworks is a common issue for students in a large classroom setting where some students might not feel comfortable asking a question.

The student response system provides a live feed indicator of "confusion" that notifies a professor when students in their class are not following the material.

In addition, the system maps the confusion level so an instructor can review later and consider specific material to revisit and perhaps remediate. In addition, a report is generated that indicates the number, topics and subtopics, which were selected by students as confusing.This approach provides a way to correct conceptual gaps of knowledge in real time, not after inadequate homework or examination results. This assists the instructor to efficiently be more aware of how the class is progressing.

Moreover, the SRS provides meaningful data to the instructor so they know exactly how many students and in what topics they were confused about for every lecture.

Moreover, whenever a student indicates that they are confused, they are automatically directed to a pertinent question, allowing for a more fluid interaction with the classroom as a whole. A natural language processing algorithms was developed to categorize similar questions together to help ensure that every question is unique so valuable lecture time is used most efficiently.

Literature on effective teaching and learning demonstrates that an active discussion is integral to the learning process, which can often be overlooked, many times due to time constraints. Due to logistical reasons, there is typically less discussion and other interactive learning in lecture halls. To increase the interaction, the newly developed SRS provides an efficient manner for an instructor to either verbally propose a question or enter the question into their computer. Upon activation, students are prompted to answer the proposed question through their device.

While students are entering their thoughts, data is streamed to the instructor's computer dashboard providing information of the how students are thinking in the classroom. The system essentially gives instructors access to actionable insights using data that has been very difficult to achieve historically. This approach could reinvigorate the Socratic method, a long-standing and effective inquiry-based teaching strategy into the large classroom setting.

RESEARCH QUESTIONS

The two research questions for this study are the following.

- ✓ **What is the anticipated effect of providing students a "confusion button" to express precisely when they begin to lose conceptual understanding?**
- ✓ **What is the attitude of faculty on students expressing real-time triggers on when they are confused and when receiving real time notifications?**

LITERATURE REVIEW

Confusion

Confusion is good. The concept of confusion is common among students, although frequently perceived as a negative outcome. While in actuality, educational theorists have promoted confusion and disequilibrium as a necessity for deep learning (Piaget, 1974).

Piaget found that when a student encounters a state of disequilibrium, they will either assimilate the information into existing schema, or accommodate, by replacing the new information for the prior information.

In this way, equilibrium returns and the concepts are theoretically positioned in the learners long term memory (Atkinson & Shiffrin, 1971).

Ideally, the learner then uses this new information to scaffold subsequent unknowns and a healthy cycle of self-regulated learning continues (Zimmerman, 1990). The cycle of confusion, resolution and higher level confusion is actually a healthy approach to making important conceptual connections.

The period of known versus unknown create a comfort/discomfort philosophy, where the learner can value the known, although realizes the unknown is the "yin" of the "yang" of complete understanding.

The philosophy of valuing confusion may remain elusive for many learners. Craig, Graesser, Sullins, & Gholson (2004) revealed that learners who spent a greater proportion of the lessons in a state of confusion exhibited significantly greater gains in learning. Liu, Pataranutaporn, Ocumpaugh, and Baker (2013) found that learning may be stronger for frustration than confusion, but is strongest when these two affective states are taken together.

This effect is strongest if the two affective states are considered together, and weakest if confusion is considered alone. Another study showed that students who were presented conflicting claims and subsequently confused performed higher on final exams (D'Melloa, Lehmanb, Pekrunc, & Graesserb, 2014). In a tangent study, (Liu, Pataranutaporn, Ocumpaugh,, & Baker, 2013) found that frustration has an even stronger effect than confusion on performance, although confusion was a key factor "as long as students were able to resolve their confusion.

Therefore, it is not merely the confusion that adds power, but the resolution that is key. So, the question remains on how to identify the critical point of confusion, and subsequently resolve the confused state, as well as by what methods can used to help clarify and return the learner to an equilibrium state. Historically, instructors have simply asked students if they are confused, with little success for many reasons.

First of all, students may be apprehensive to speak for fear that peers will perceive them unintelligent (Hargreaves, 1984). Secondly, many times learners simply are so completely behind in their understanding that they are unable to articulate a clear, sensible question. Finally, the instructor's open-ended prompt does not initiate the learners ability to retrieve sufficient information from their long-term memory, so that they may be able to realize the point of their confusion sufficiently to ask a question (Partin, 1979).

Therefore, the ability to identify the beginning of learner confusion in an unobtrusive way is both critical to understanding and can act as a redefinition of instruction, which has previously been nearly impossible (Puentedura, 2006; Hargis, & Soto, 2015). To attempt to gain an understanding of student questions, historically, instructors have employed various methods of Student Response Systems.

Student Response Systems (SRS)

Research has shown that Student Response Systems (SRS) can increase student engagement and participation (Heaslip, Donovan, & Cullen, 2014; Galal, Mayberry, Chan, Hargis, & Halilovic, 2015). In addition, Barnett (2006) has shown that SRS provide students more opportunities to respond, thereby encouraging reflection and metacognitive processing; timely feedback to assist in reducing misconceptions and solidifying conceptual understanding; and opportunities for formative assessment providing venues for just in time remediation. Hall, Collier, Thomas, and Hilgers (2005) has shown that SRS can create an open, accessible learning environment where all learners feel open to contribute.

They can also assist instructors in assessing student comprehension and developing classroom activities that allow for the application of key concepts to practical problems. There are many types of Student Response Systems.

Student response sytems include basic hand raising to raising colored sheets of paper to more contemporary forms of using technology, such as clickers and applications including www.polleverywhere.com, www.padlet.com, www.kahoot.com, www.plickers.com, http://goformative.com, www.twitter.com and even an audience participation function on Google Slides. Although these SRS's are beneficial, they require substantial efforts in planning and perhaps even more costly is the class time to set up, gathers, interpret and act on the results.

Advance use of SRS using instructional technology has dramatically advanced using mobile learning (mLearning), most notably from tablets and/or smartphones. Research in this area has shown significant enhancement in student engagement; faculty perceptions; innovative approaches to technical challenges; and development and evaluation of new digital content (Cavanaugh, Hargis, Kamali, & Soto, 2013; Hargis & Soto, 2013; Hargis, Cavanaugh, Kamali, & Soto, 2013; Hargis, Cavanaugh, Kamali, & Soto, 2014; Davison, & Hargis, 2016). One of the major advantages of using technology is the ability for rapid, graphical feedback in various, flexible forms. The instructor can present traditional bar and pie graphs, or more creatively portray qualitative data in a word cloud frequency diagram (Greer, & Heaney, 2004). The ability to quickly assess student needs and get visuals on the same can provide access to more ways that students process information.

METHODS

Setting

This study was conducted at a large research intensive public university located in the southwest United States. The data was collected through individual face to face interviews with faculty members.

There was no attempt to randomize the population, and at the same time, there was nothing in particular about the faculty members selected for the study, except that they agreed to be interviewed.

Every interview involved the primary author arranging a meeting with the faculty member in their office at a time that was convenient for them to meet. The time of most interviews was between 30 and 60 minutes. During this time, the interviewer verbally asked each question on the survey (Appendix A).

Note that the survey had two parts, one before the discussion of the idea and one after the discussion. In both cases, the same interview approach was followed. The interviewer asked the questions and recorded the faculty member's responses.

Participants

The participants for this study included 65 faculty members at the same southwest U.S. university, selected through a snowball sampling technique. All of the participants were contacted through the university email system.

Out of the 65 faculty interviewed, 62 were asked the full set of interview questions (Appendix A), and three were only asked a subset because they were not teaching faculty, but held an academic coordinator or research role.

Figure 1. and 2. lists the number and background of the faculty that were surveyed.

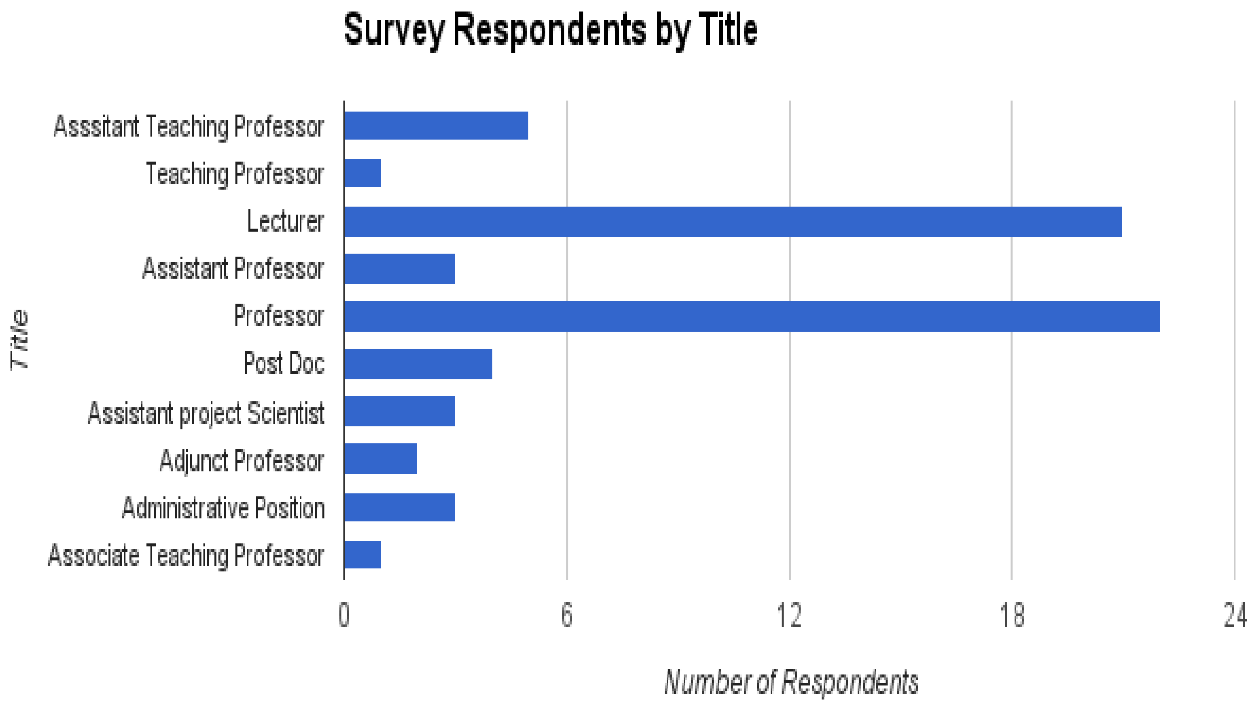

Figure 1.
Survey Respondents by Teaching Title

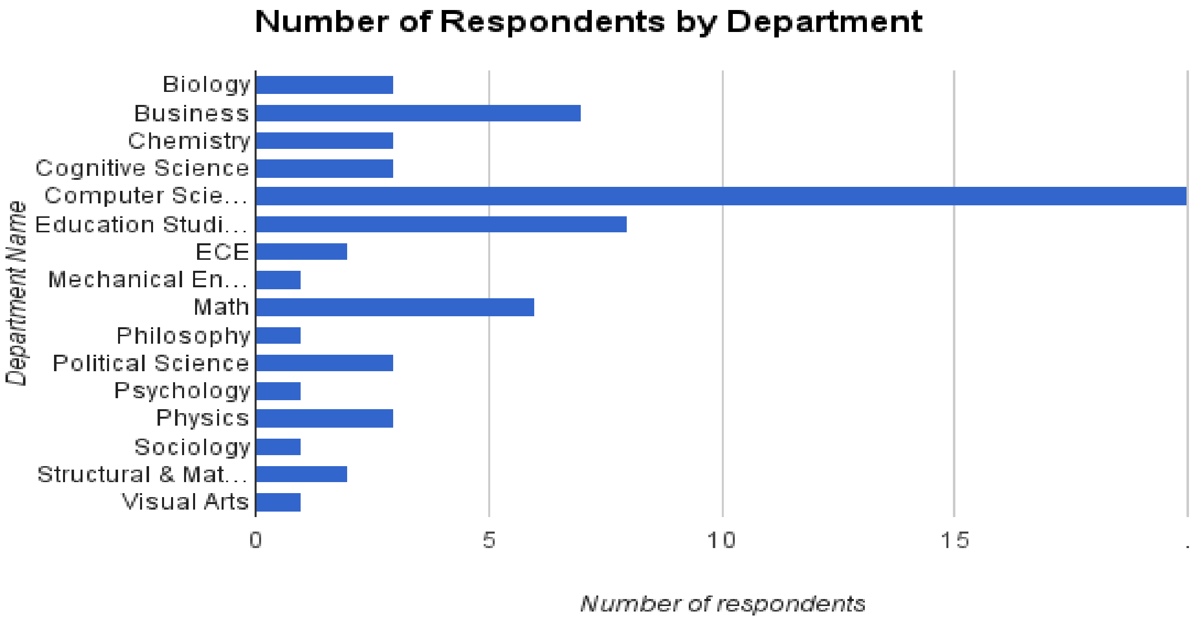

Figure 2.
Survey Respondents by Department of Appointment

RESULTS

Sixty-two participants completed all of the questionnaires. The data were analyzed and each of the hypotheses explored. The corresponding results are described below.

The hypotheses were designed to measure the;

- ✓ **Anticipated effect of providing students a "confusion button" to express precisely when they begin to lose conceptual understanding; and**
- ✓ **Attitude of faculty on students expressing real-time triggers on when they are confused and of faculty when receiving real time notifications?**

The data include:

- ✓ **Figure 1: Title, Department and Number of Faculty**
- ✓ **Figure 2. Segmentation Survey Analysis**
- ✓ **Table 1. Student Evaluation of Instruction Results for Math Class**
- ✓ **Figure 3. Regression Tree Diagram for Engineering Classes.**
- ✓ **Figure 4: Scatter plot showing correlation between Mean**

Professor Recommended Class ratings and Mean Recommended Class Ratings

Table 1.
Student Evaluation of Instruction Results for Math Class

Term	Recommend Class	Recommend Instructor	Study Hours/ Week	Average Grade Expected
Average	**86.4**	**86.7**	**6.5**	**3.3**
Maximum	**100**	**100**	**-**	**4**

Note: Teaching professors were included in the Professor category.

Figure 3 presents an initial data regression analysis based on student evaluation data. The figure demonstrates how student recommended professor ratings vary with different variables, such as class ratings, homework, time etc.

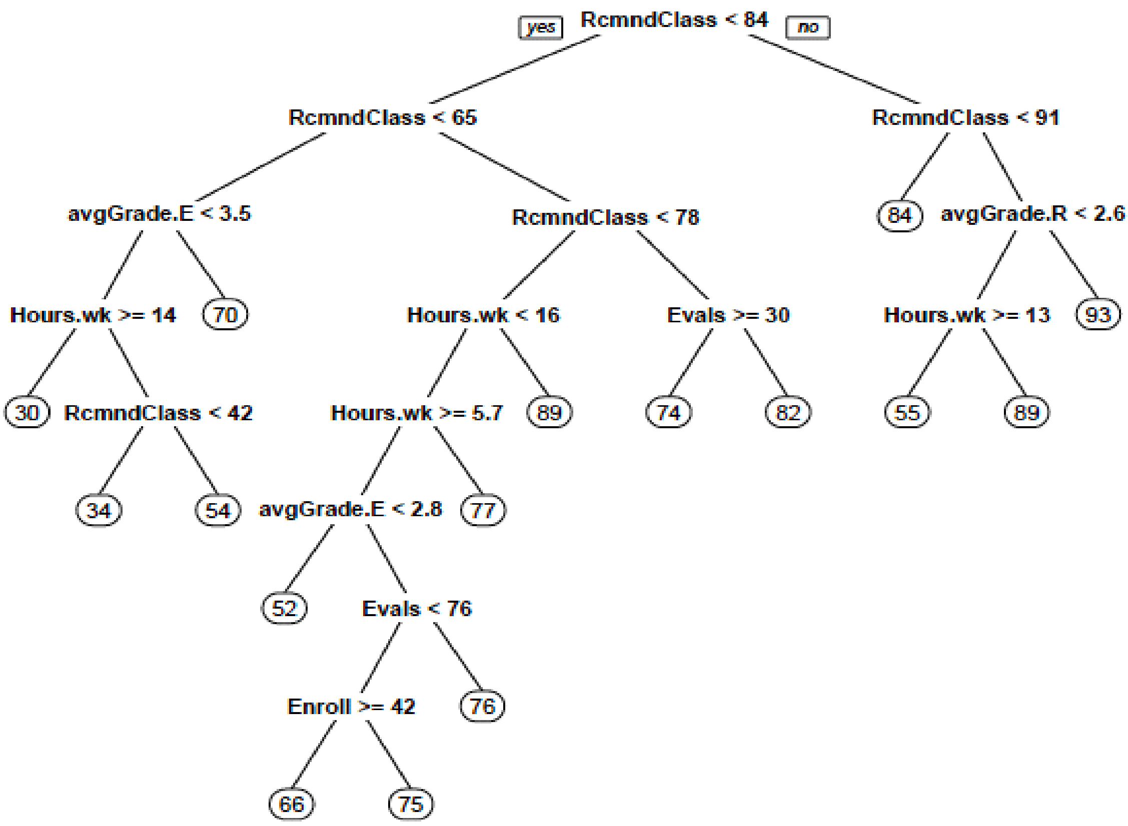

Figure 3.
Regression Tree Diagram.

The final numbers in the boxes are student recommended professor ratings (out of 100). For example, if you select a class with a recommended class rating less than 84 and greater than 65 and it is also more than 78. The recommended class rating, therefore, is between 84 and 78, then the most important variable for determining predicted student rating depends on the number of evaluations submitted.

DISCUSSION

The Regression Tree Diagram (Figure 3) was made using a statistical software called R in which pre-built statistical packages were called to generate the classification tree. Data was input into the model, mined from student evaluations in particular for all engineering courses taught. Some courses, such as Computer Science Engineering, had student evaluation data since the year 2004, while others did not contain as elaborate history of student evaluations.

As a result, data from a number of years was removed to make sure the student evaluation scores from every department (Bioengineering, Computer Science and Engineering, Electrical and Computer Engineering, Mechanical and Aerospace Engineering, NanoEngineering, Structural Engineering) started from the same year. The goal was to predict a professor's recommended student evaluation rating (out of 100). The numbers represent the predicted student evaluation recommended Professors scores (out of 100).

The finding may be of interest is the (heaviest weighted) factor in predicting how students may rate their professors, which seems not to be based on whether the class was difficult or easy; or if the homework required substantial time; or if the average course enrollment was high or low; but on whether the class traditionally had a high recommended class rating. For example, for a professor who is teaching a class that has historically been 'Liked' by students as judged by their hgh recommended student ratings, i.e., greater than 91%.

In addition, when the average grade (Grade Point Average) received by students in the course was more than 2.6 (a B- or better), the professor's recommended instructor rating produced an average score of 93%.

Perhaps even more surprising is that the variable Average Grade Received is the third most important factor, even more important than Average Grade Expected. This is unexpected as student evaluations are completed by students before final exams are taken and hence students do not know their ultimate course grade.

It can, however, be speculated that the students already have a good idea of how they are doing in the class on the spectrum of grades as they typically have access to the way the grade would be calculated based on the homework, quiz, midterm, and finals scores.

So the variable, Average Grade Received, may in fact be very similar to Average Grade Expected.

If this is in any way representative of the state of evaluations, theoretically, a professor could adjust their student evaluation scores by teaching a traditionally 'Liked' course and maintain the average course grade as a "B" or better.

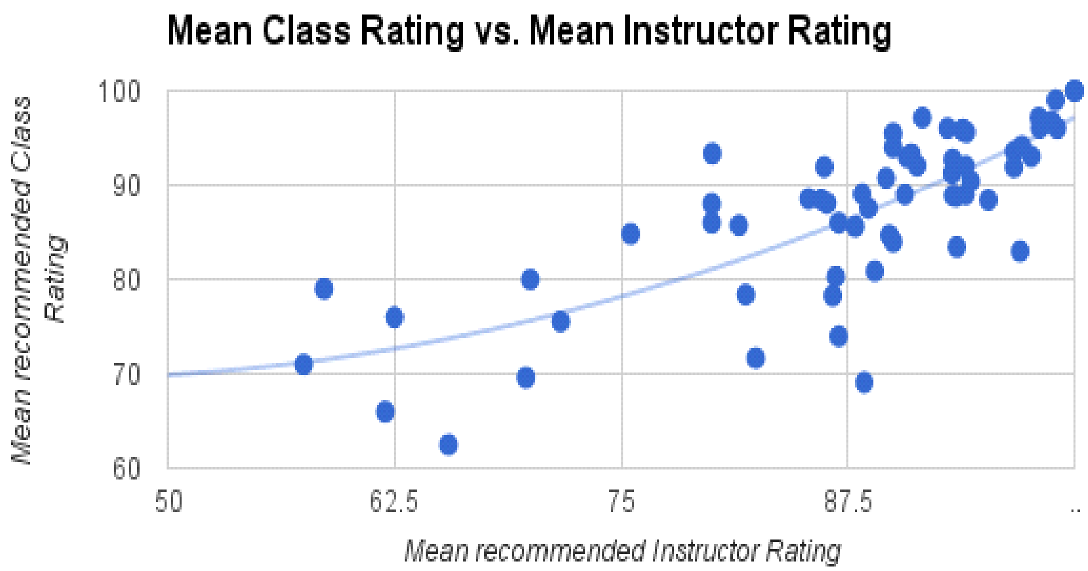

Figure 4.
Scatter plot showing correlation between Mean Professor Student Evaluation Recommended Class ratings and Mean Recommended Class Ratings

As shown in Figure 4, most responses were received by professors followed by Surprisingly, full tenured professor's response rate was the most and it is suspected that was a result of their interest in helping students along with the sense of responsibility of improving education for students by improving their own teaching skills.

Another reason could be they are in pursuing of an efficiency model for high quality teaching. If an automated student response system could provide accurate, meaningful, actionable data - such as could be found through a "confusion" button, this may increase student performance. If this happened, the result would be an asset for both the student (higher grades); and the faculty success, as well as possible higher student evaluations.

Hypothesis 1
What is the anticipated effect of providing students a "Confusion Button" to express precisely when they begin to lose conceptual understanding; and When students are able to indicate their confusion in a highly discreet and low threshold manner, this empowers them to express clearly the concepts, which they may not fully understand and also provides the opportunity for real time clarification from the instructor.

A critical component is both noticing the confusion and the ability to seamlessly address it with minimal disruption of the course progress.

As a result of these factors, faculty has expressed their expectations that students will embrace a tool that allows them easy access to participate in their own learning.

Perhaps just as important, integrating the student response system provides students with frequent opportunities to consciously think about their thinking and to develop the abilities to recognise topics how they process the information.

Therefore, appropriate use of these student engagement tools can help students learn valuable metacognition by recognising when they are confused and acting upon that belief.

The availability of a "Confusion" button creates a more interactive learning environment, recalibrating the tone of a traditional static classroom and reinforces that being in a state of confusion is not only acceptable, but can often become a more efficient and deeper path of learning, applying and retaining conceptual frameworks.

By providing students an opportunity to reflect on their confusions, while they are occurring, they have a more accurate perception of their lack of knowledge and hence we expect that such students would put in more time to improve on those areas. (Pintrich, 2002)

Approaching teaching and learning in this fashion can be a substantial change from traditional approaches as many students arrive in post-secondary settings with very little metacognitive lecturers.

One reason for this result could be that since lecturers success is more closely tied to teaching, they may spend more time to improve their own teaching while professors who are not tenured yet may be more focused on their research (to secure tenure) and as a result did not reply as frequently, abilities (Hofer, Yu, & Pintrich, 1998; Pintrich, McKeachie, & Lin, 1987).

This may be a major reason why increasing their abilities in this area is an interest of both instructors and students, as a key factor of teaching the ability to become a self-regulated learner. Winne (1997) found that self-regulated learners are students whose academic learning abilities and self-discipline make learning easier so motivation is maintained.

In addition to modifying individual student attitudes towards the concept of confusion, the learning culture could be updated to reflect recent literature on effective teaching. Faculty have expressed they predict that students would become more open to express their current understanding individually, which could provide a model for other students to engage and subsequently create a more inclusive and collaborative learning experience.

Hypothesis 2

What is the attitude of faculty on students expressing real-time triggers on when they are confused and of faculty when receiving real time notifications? Another potential positive effect when using the "Confusion Button" could be on how faculty prepare, provide and think about their instructional philosophy.

In general, faculty care about students and teaching, although many do not have an instructional background or have minimal opportunities for faculty development in the area of teaching and learning.

Therefore, by providing easy-to-use applications, which can capture real-time student notifications on when they are confused on a topic, faculty can rethink their instructional approach.

Frequently, instructors are sharing information in ways that they learned which a normal approach is. However, if students are processing in different ways, it is difficult for the instructor to realize this and perhaps more importantly, precisely when this is occurring, so they can adapt.

Another benefit of this learning tool would be to assist faculty with timely and focused faculty development services.

Whenever faculty redesign their courses or instructional methods, there will be opportunities for adjustment, such as allowing faculty to think about how they teaching in a different, perhaps more informed way (Tanner, 2012).

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APPENDICES

Appendix A: Professor Survey

- ✓ **What is the size of classes you typically teach?**
- ✓ **How many years have you been teaching?**
- ✓ **Do you tend to teach more lower or upper division courses?**
- ✓ **Do the courses you teach change? How often?**
- ✓ **Do you use Clickers or a similar device in your classes? How do you feel about them?**
- ✓ **What tools do you use to teach (Powerpoint, handwritten notes, etc.)?**
- ✓ **What methods do you use to assess student comprehension during lecture?**
- ✓ **How many students ask questions in class? Are they the same students?**
- ✓ **Is it easy to determine when students are confused during lecture?**
- ✓ **Do you have to adapt lectures spontaneously? How often?**
- ✓ **Would you like to measure attendance?**
- ✓ **How do you feel about students using mobile devices in the class for learning?**
- ✓ **Do you do in class discussions by forming small groups? What are its limitations?**
- ✓ **What's the purpose of doing these discussions?**
- ✓ **Do you podcast lectures? If not would you be ok recording the lecture and sending it to students?**
- ✓ **What would you say is one thing you wished Clickers had?**
- ✓ **What is the one thing you wished you knew about students during lecture?**
- ✓ **How do you go about the grading process? Do you provide a key to your graders? Are you selective about who grades your student's exams etc? How much time does it generally take to return exams**

Appendix B. Post Device Feature Discussion Survey

- ✓ **If you were interested in a product like this, how would you find about it?**
- ✓ **Do you discuss educational technology apps with your colleagues? How often?**
- ✓ **Where would be your preferred place to place a device - pocket, belt or shirt?**
- ✓ **Would you be okay wearing a microphone in addition to the one you already wear?**
- ✓ **Every class has students that are strong, weak, and average. While preparing for lectures which group do you try to target?**
- ✓ **Who else do you believe would be good to speak to about this learning tool?**